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Effects of male precocity on progeny of rainbow trout

F. Fredrich, K. Kohlmann, and W. Steffens

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Effects of male precocity on progeny of Rainbow Trout

by

F. FREDRICH, Diplomaed Biologist, K. KOHLMANN, Diplomaed Fishery Engineer, and Prof. W. STEFFENS, D Agr
Institut für Binnenfischerei [Inland Fishery Institute], Berlin-Friedrichshagen [GDR]

In modern salmonid culture, the manipulation of reproductive biological traits plays a major role. Thus, breeding work has focussed on the absolute and relative fecundity of individual females, as well as the average weight of eggs (DONALDSON and OLSON 1957, GALL 1975, GALL and GROSS 1978, SCHMIDT 1980, and REICHLE 1983). Breeding techniques have been applied also to cause seasonal shifts of the spawning period (SCHMIDT 1982 and 1983, MAROCCO 1982). Especially in intensive salmon production, maintaining the juvenile state until the fish have reached marketable size has had considerable economic importance. Also in this area, breeding techniques (selection, sterilization) have been used (GJERDE 1984, HUNTER et al. 1982, BREGNBALLE and JOKUMSEN 1985, and JALABERT et al. 1975).

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In the intensive trout farming of the GDR, precocious males in the first year of life occur with weights from 50 to 200 g. Their reproductive maturation depresses their growth, increases mortality and aggressiveness, and impairs the quality of the meat. Because of the onset of reproductive maturity, the precocious males reach marketable size much later than the rest of the stock, which also leads to higher food costs. On the other hand, precocious males yield fertile sperm with the same concentration and motility as sperm of normal males. This makes their use as breeding stock very economical, since there are savings in holding capacity and food.

It is therefore worthwhile to determine whether the incidence of male precocity is controlled by environmental factors-- i.e., phenotypically, so that it is not hereditary-- or whether it is a fixed hereditary feature of the genotype. This has implications for the usefulness of precocious males in rainbow trout hatcheries.

Material and Method

To obtain progeny of identical maternal and paternal provenance, we performed a diallelic crossing experiment with three lines of normally maturing rainbow trout. Also, a mixture of sperm from three precocious males not related to the females was mated with mixed samples of eggs from each line (Table 1).

The lines of normally maturing fish had average weights of 1577 g (females) and 1475 g (males), and with very good holding conditions, they were ready for spawning in the second year. The precocious males (PM) were ten months old, with an average weight of 80 g.

The insemination date was taken as day 0 of development. All progeny were incubated and reared under uniform conditions. Weight was sampled every six weeks. Individual weights were recorded at the beginning (day 128) and end (day 360 and day 402) of fattening. The number of stock per basin had to be reduced with the growth of the fish. The progeny of all crossed (2, 3, 4, 6, 7, and 8), inbred (1, 5, and 9) and PM groups (10, 11, and 12) were assessed together.

Because of their different affinities, the inbred groups and the PM groups were not compared directly with each other.

Results

Frequency of male precocity

Among 214 male progeny slaughtered after 360 days, 52 (= 24.3 % of all males, and 10.8 % of all fish investigated) were precocious. The precocious males were not evenly distributed among the different types of progeny. The proportion of precocious males was conspicuously high in the PM groups, and lowest in the crossed groups (Table 2).

The higher incidence of male precocity in PM groups compared to crossed groups was significant at a high level ($\alpha = 0.001$). Further investigations after 402 days confirmed this result. Fifty-nine out of 479 fish were precocious males (= 12.31 %), and they were concentrated especially in the PM groups (Table 3).

	A	B	C	PM
A	1	2	3	10
B	4	5	6	11
C	7	8	9	12

Table 1. Mating combinations

Nachkommen-kategorien (1)	Anzahl juveniler ♂♂ (4)	Anzahl PM (5)	Verhältnis juveniler ♂♂ : PM (6)	Prozentualer Anteil der PM an der Gesamtanzahl (7)
Kreuzung (2)	91	10	9 : 1	4.17
Inzucht (3)	42	11	4 : 1	9.17
PM	30	31	1 : 1	25.83

Table 2. Ratios of juvenile and precocious males in crossed, inbred, and PM groups after 360 days.
1- type of progeny 2- crossed 3- inbred 4- number of juvenile males 5- number of precocious males 6- ratio of juvenile males to precocious males 7- percentage of precocious males in the total number [Commas represent decimal points.]

Nachkommen-kategorien (1)	Anzahl untersuchter Fische (4)	Anzahl PM (5)	Prozentualer Anteil der PM an der Gesamtanzahl (6)
Kreuzung (2)	239	12	5.02
Inzucht (3)	120	13	10.83
PM	120	34	28.33

Table 3. Numbers of precocious males in crossed, inbred, and PM groups after 402 days.
1- type of progeny 2- crossed 3- inbred 4- number of fish investigated 5- number of precocious males 6- percentage of precocious males in the total number

Alter (1)	Kreuzungsgruppen (2)	Inzuchtgruppen (3)	PM-Gruppen (4)
166 d	4.48 ± 1.61	4.26 ± 1.25	3.92 ± 1.67
360 d	181.44 ± 44.84	168.11 ± 45.55	158.78 ± 46.66
402 d	273.67 ± 74.36	260.00 ± 70.66	223.74 ± 71.57
FQ (5)	1.50	1.55	1.64

Table 4. Average individual weight of different types of progeny.
1- age 2- crossed groups 3- inbred groups 4- PM groups
5- food quotient

Once again, the higher incidence of male precocity in PM groups compared to crossed groups was statistically significant at a high significance level.

The investigations showed an incidence of precocious males in crossed groups of approximately 5 %. Their frequency was twice as high in inbred groups compared to crossed groups; this difference is only weakly significant statistically, but it suggests a negative effect of inbreeding on reproductive maturation. The large proportion of precocious males in the total stock in the PM groups is especially striking. About half of all the males, or a quarter of the total progeny inherited the precocity of the male parent, making the incidence of male precocity five times higher in the PM groups than in the crossed groups. No findings are available yet regarding the sexual development of female progeny of precocious male parents.

Similar results were obtained by THORPE et al. for Atlantic Salmon (*Salmo salar*) (1983) and by IWAMOTO et al.

(1984) for Coho Salmon (*Oncorhynchus kisutch*). THORPE et al. observed a significantly ($\alpha = 0.01$) higher incidence of precocious males one year of age (parr) when the male parents also matured as parr. Male parents reaching reproductive maturity at the age of 2^+ and 3^+ were compared. When precocious parr males reproduced, the frequency of mature parr males increased in the second generation by a factor of 5.4, and again in the third generation by a factor of 1.7.

Among 4980 progeny of precocious and normal males of *Oncorhynchus kisutch* mated with normal females, IWAMOTO et al. (1984) found 175 precocious males (= 3.75 % of the progeny). The incidence of male precocity was 4.6 times as high among progeny of precocious male parents than among progeny of normal males. Soviet authors reported that increased fishing of ascending migrant males of *Oncorhynchus nerka* made it easier for stationary freshwater dwarf males to survive to reproduction, leading to increased numbers of dwarf males and a decrease in the productivity (catch yields) of the runs. They feared that as this process continued, the salmon stock would degenerate and a valuable food species would be lost.

No comparable studies have been published yet for rainbow trout.

Growth studies

Growth of different types of progeny

Growth in weight of the three types of progeny was very different. At the first weighing on day 128, the identical maternal influence still concealed these differences. By day 166, the mean individual weights of the crossed and inbred groups were significantly higher ($\alpha = 0.001$) than those of the PM groups (Table 4). Also the difference in the mean individual weights of crossed and inbred fish was significant ($\alpha = 0.025$). Throughout the fattening period, crossed progeny grew distinctly faster than inbred progeny or progeny of precocious males. At the age of 360 days, the mean individual weights for the crossed groups were significantly higher ($\alpha = 0.001$) than for the inbred and PM groups. After 402 days, the growth lag of the PM groups had widened further. The mean weights of PM progeny were lower at a high level of significance ($\alpha = 0.001$) than those of crossed and inbred progeny. However, the difference between the mean individual weights of crossed and inbred groups was no longer significant, because the samples were smaller and the relative difference reduced.

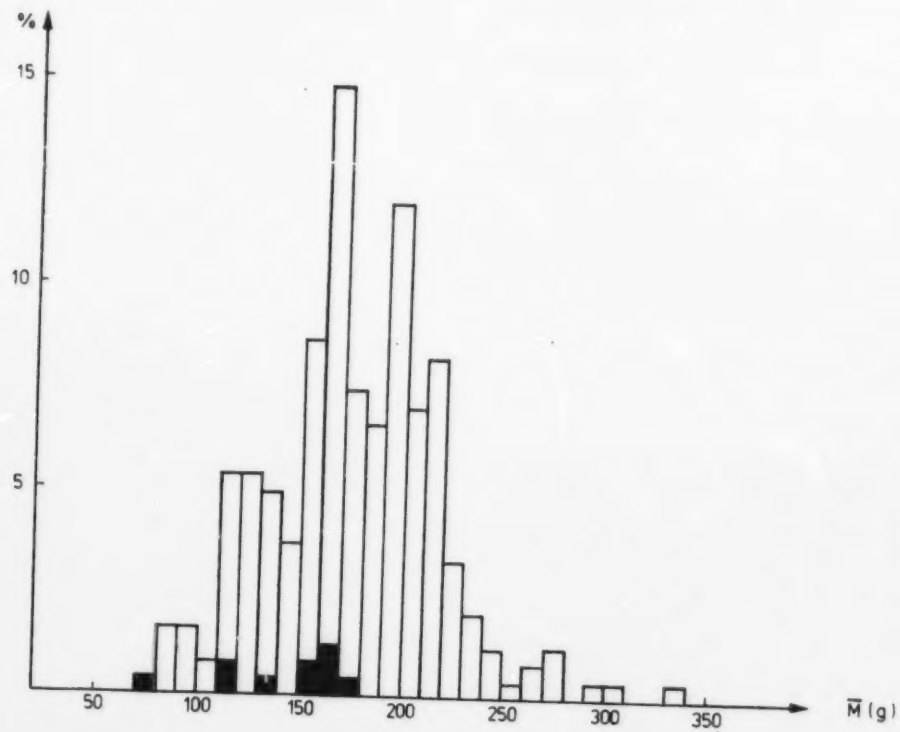
Food costs were lowest in the groups with the best growth (crossed progeny) and highest in the PM groups (Table 4). This confirms the close link already demonstrated earlier between good growth and good food utilization (FREDRICH 1983, 1986).

Growth in relation to the maturation stage of the gonads

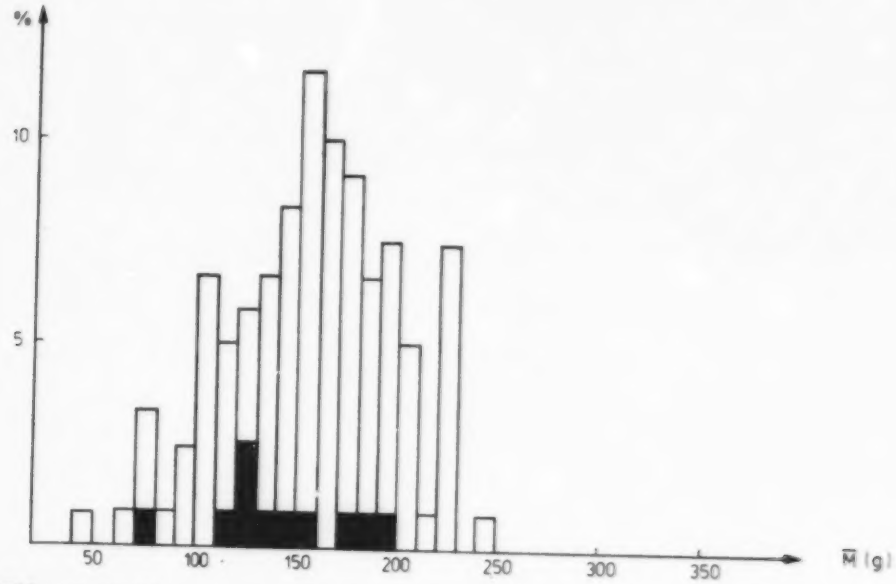
The analysis of growth shows that juvenile and ripe fish had very different mean weights in all three types of progeny. Particularly in the PM groups, it is striking that the ripe males are concentrated in the lower weight classes (Figure 1).

Figure 1 (a to c). Frequency distributions of mean weights in the three types of progeny (black columns represent the approximate proportion of precocious males).

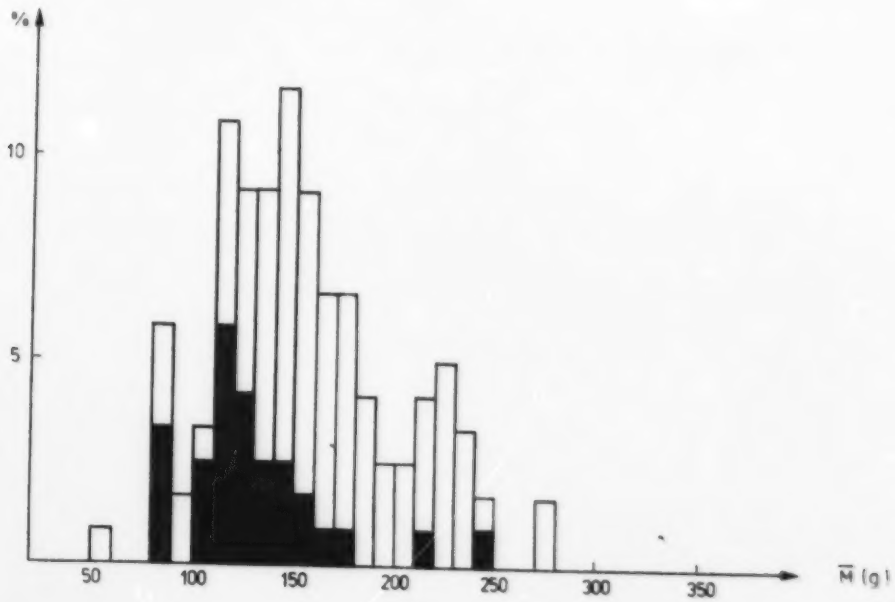
a- crossed groups



b- inbred groups



c- PM groups



After 360 days, juvenile fish of all three types of progeny weighed significantly more than the precocious males (Table 5).

The differences in the mean individual weights of the juvenile fish were highly significant ($\alpha = 0.001$) for crossed vs. inbred groups, and for crossed groups vs. PM groups. But weight differences between precocious males of all three categories were not significant, although a tendency to lower weights is discernible in the PM groups.

After 402 days, the precocious males lagged even farther behind compared to the juveniles. The absolute differences in the mean individual weight of juvenile fish and precocious males had become even greater in all three categories (Table 6). They were highly significant ($\alpha = 0.001$).

Both juveniles and precocious males had significantly higher weights ($\alpha = 0.05$) in the crossed groups than in the PM groups. The differences between crossed and inbred groups were not significant.

		Kreuzungsgruppen (3)	Inzuchtgruppen (4)	PM-Gruppen (5)
Juvenile Fische (1)	n	330	198	80
	M ± S	175.87 ± 41.74	156.26 ± 42.66	142.88 ± 44.74
Reife Milchner (2)	n	10	11	21
	M ± S	142.20 ± 31.20	140.64 ± 34.63	129.94 ± 35.41

Table 5. Mean individual weight (in grams) of juvenile fish and ripe males at the age of 360 days
1- juvenile fish 2- ripe males 3- crossed groups
4- inbred groups 5- PM groups

		Kreuzungsgruppen (3)	Inzuchtgruppen (4)	PM-Gruppen (5)
Juvenile Fische (1)	n	227	107	66
	M ± S	277.20 ± 66.71	270.64 ± 64.16	269.56 ± 63.75
Reife Milchner (2)	n	12	13	24
	M ± S	190.25 ± 39.19	180.77 ± 47.30	159.62 ± 58.39

Table 6. Mean individual weight (in grams) of juvenile fish and ripe males at the age of 402 days
1- juvenile fish 2- ripe males 3- crossed groups
4- inbred groups 5- PM groups

The facts can be summarized as follows:

1. After 402 days as well as after 360 days, juveniles of crossed groups were heavier than those of PM groups.
2. The difference observed between the mean individual weight of precocious males in crossed and in PM groups after 360 days becomes larger, and after 402 days, is statistically significant.
3. Precocious males in all three categories have lower weights than juvenile fish.
4. The low mean weights observed in the PM groups are caused by the higher frequency of male precocity and the poor growth of juveniles as well as ripe males in these groups.

As regards the reasons for the lesser weight of juveniles and mature males in the PM groups as opposed to the crossed groups, initially we can only offer conjectures. Because the egg material was identical for both types of progeny, maternal influence can be ruled out. Paternal influence would be conceivable. Since male parents of different provenance produced the crossed groups and the PM

progeny, in addition to the direct influence of the genetic factors responsible for the precocity, there could also be an influence by other genetic factors in which these provenances differ. It is also possible that the occurrence of so many precocious males causes social stress for all fish in a holding unit, and this leads to depressed growth. 5. The difference in the weight of juvenile fish in the crossed and the inbred groups detected after 360 days became smaller, and after 402 days, was not significant.

The initial difference could have been caused by depressed growth in the inbred group or by heterosis in the crossed group. The retrogression of this difference corresponds with findings by KLUPP (1979).

Conclusions

The use of precocious rainbow trout males as breeding stock involves considerable disadvantages for the progeny. On the one hand, precocious males with depressed growth occur more frequently among the progeny (25 % of the progeny). Their aggressiveness leads to increased social stress for all fish. The high proportion of body weight comprised by the testes (on average 7.0 %) diminishes the useful portion of the fish. On the other hand, it was demonstrated experimentally that also juvenile progeny of precocious males exhibit poor growth. This poor growth of the progeny of precocious males is closely connected with

their poor food utilization. Therefore precocious males should not be used for breeding. Since the possibility that mature fish in commercial stock may be precocious can not be ruled out, they, too, should be excluded from reproduction completely. Moreover, with repeated use of males from commercial stock, there is a danger of hastening the reproductive maturation of the males and thus increasing the proportion of ripe fish in the stock.

Summary

A diallelic crossing experiment was performed using four female and four male parents from each of three lines of normally maturing rainbow trout. In addition, mixed samples of eggs from each line were inseminated with mixed samples of sperm from three precocious males (= PM) which were not related to the females. The incidence of precocious male progeny was higher in the PM groups than in the crossed groups with a high level of statistical significance (α= 0.001). Higher incidence of male precocity in inbred groups as compared to crossed groups was significant at a level higher than the usual α (0.2). Beginning on day 166 of development, the PM groups exhibited lower mean individual weights than crossed and inbred groups, at a high level of significance (α= 0.001)-- primarily because of the higher incidence of male precocity in the PM groups. Ripe males from commercial fish stock should not be used for repro-

duction, since the possibility can not be ruled out that they may be precocious.

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